United States Patent [19]

Ohi

[11] **Patent Number: 5,043,642**

[45] **Date of Patent: Aug. 27, 1991**

[54] **APPARATUS FOR CONTROLLING BLOWER MOTOR OF AUTOMOBILE AIR-CONDITIONER**

[75] Inventor: **Shinichi Ohi**, Konan, Japan

[73] Assignee: **Diesel Kiki Co., Ltd.**, Tokyo, Japan

[21] Appl. No.: **504,139**

[22] Filed: **Apr. 3, 1990**

[30] **Foreign Application Priority Data**

Apr. 6, 1989 [JP] Japan 1-87374
Apr. 25, 1989 [JP] Japan ..... 1-48463[U]

[51] **Int. Cl.**[5] **H02P 6/02**
[52] **U.S. Cl.** **318/254**; 318/138
[58] **Field of Search** 318/138, 254, 439, 481; 165/16, 43, 42, 41

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,999,108	12/1976	Tanikoshi	318/138
4,250,435	2/1981	Alley et al.	318/254 X
4,317,072	2/1982	Goof et al.	218/138
4,456,055	6/1984	Yoshimi et al.	165/43 X
4,458,583	7/1984	Fukui et al.	165/16 X
4,546,293	10/1985	Peterson et al.	318/138 X
4,763,052	8/1988	Lundin et al.	318/254
4,806,833	2/1989	Young	318/481 X
4,858,676	8/1989	Bolfik et al.	165/43 X
4,914,924	4/1990	Takahashi	165/43 X

Primary Examiner—Bentsu Ro
Attorney, Agent, or Firm—Wenderoth, Lind & Ponack

[57] **ABSTRACT**

An apparatus for controlling a brushless type blower motor of an automobile air conditioner includes a rotational speed setting unit for setting a rotational speed of the brushless motor, a drive unit for driving the brushless motor according to the speed of rotation set by the rotational speed setting unit, and a switching control unit for controlling the excitation timing of the brushless motor achieved by the drive unit. The driving unit includes a waveform storage unit for changing the waveform of a voltage to be impressed to the brushless motor. The waveform storage unit outputs a sine waveforms, a trapezoidal waveform or a square waveform according to the rotational speed set by the rotational speed setting unit.

1 Claim, 7 Drawing Sheets

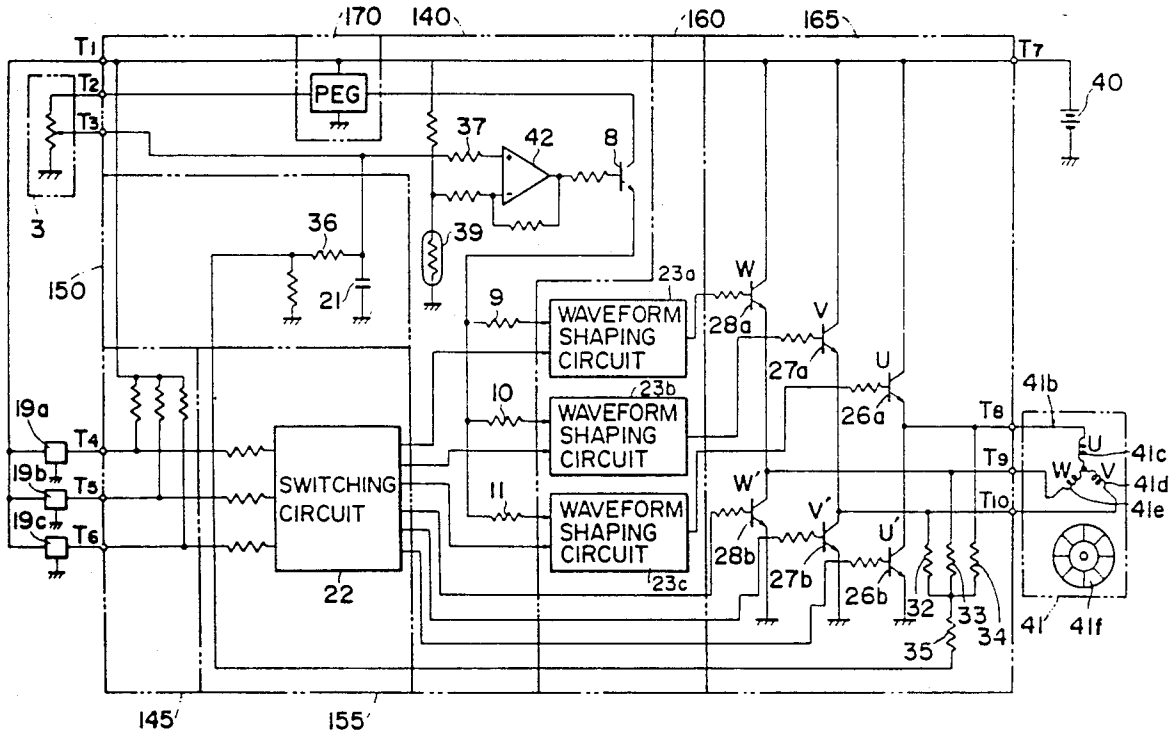


FIG. 1

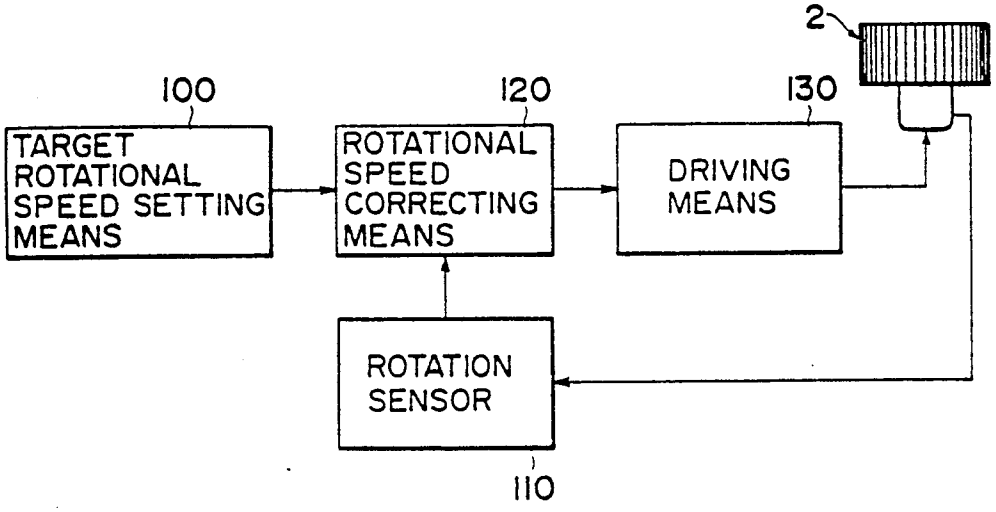

2
100
120
130
TARGET ROTATIONAL SPEED SETTING MEANS
ROTATIONAL SPEED CORRECTING MEANS
DRIVING MEANS
ROTATION SENSOR
110

FIG. 2

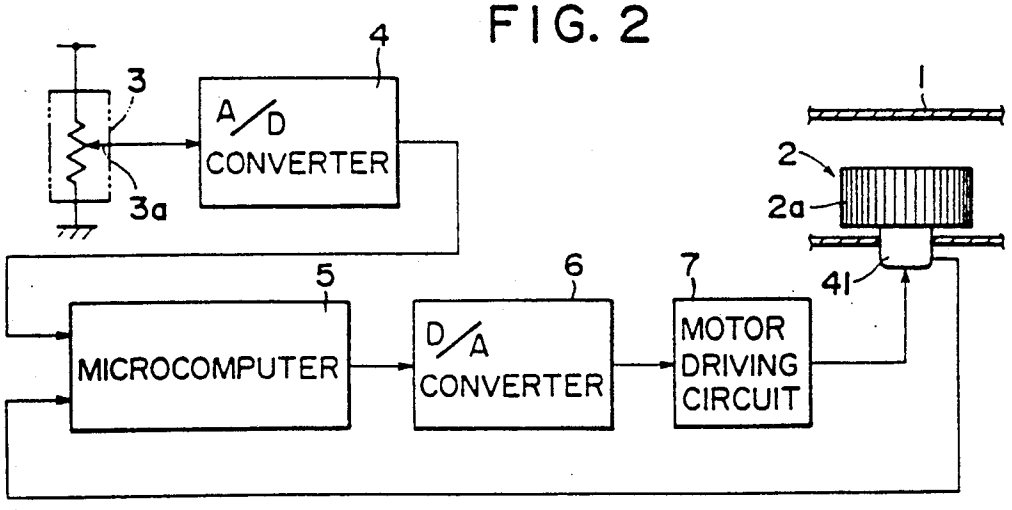

4
3
A/D CONVERTER
3a
1
2
2a
41
5
6
7
MICROCOMPUTER
D/A CONVERTER
MOTOR DRIVING CIRCUIT

FIG. 3(a)

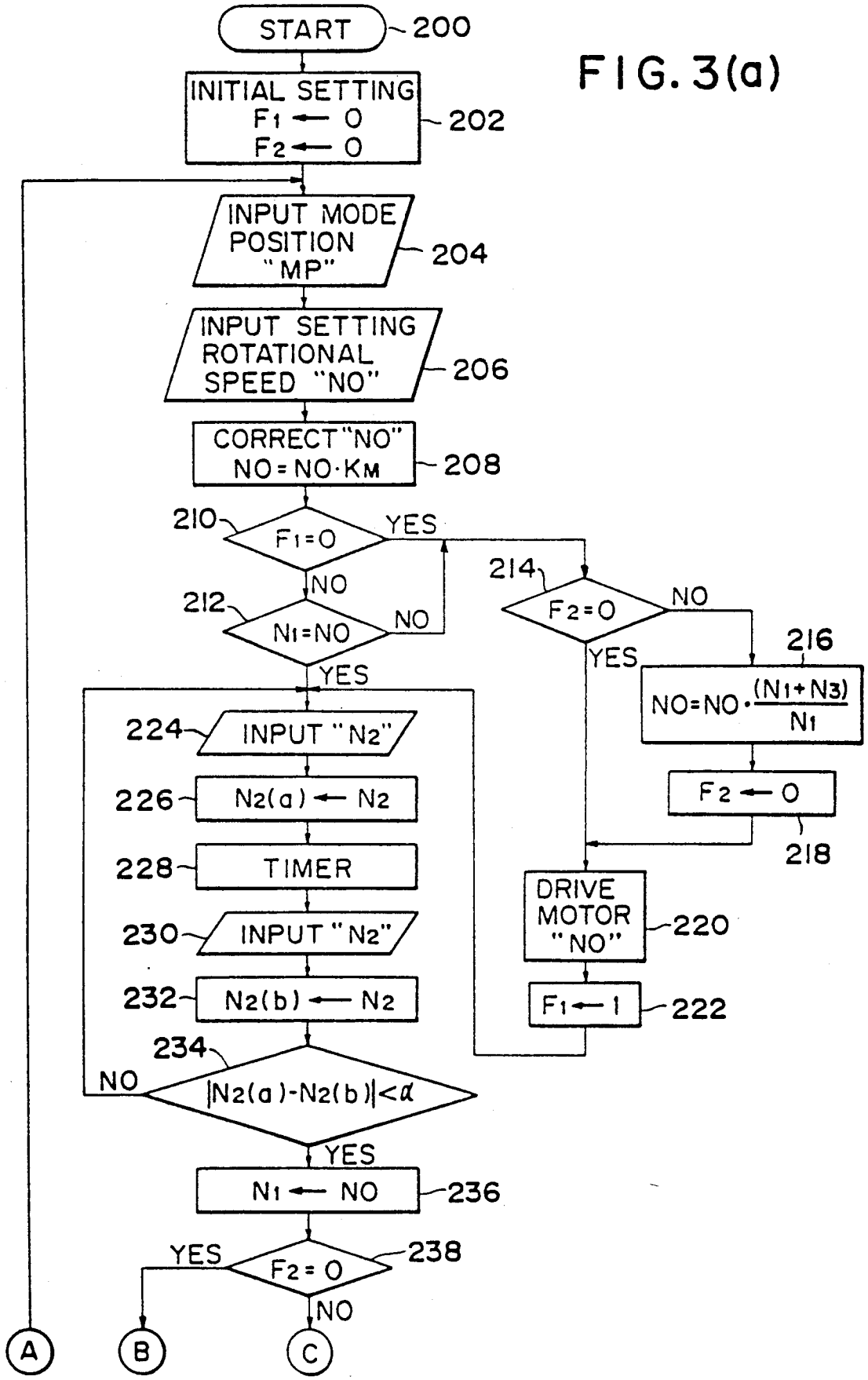

START
200
INITIAL SETTING
F1 ← 0
F2 ← 0
202
INPUT MODE POSITION "MP"
204
INPUT SETTING ROTATIONAL SPEED "NO"
206
CORRECT "NO"
NO = NO·KM
208
210
F1=0
YES
NO
212
N1=NO
NO
YES
214
F2=0
NO
YES
216
NO=NO·(N1+N3)/N1
F2 ← 0
218
224
INPUT "N2"
226
N2(a) ← N2
228
TIMER
230
INPUT "N2"
232
N2(b) ← N2
234
|N2(a)-N2(b)|<α
NO
YES
DRIVE MOTOR "NO"
220
F1 ← 1
222
N1 ← NO
236
238
F2=0
YES
NO
A
B
C

FIG. 3(b)

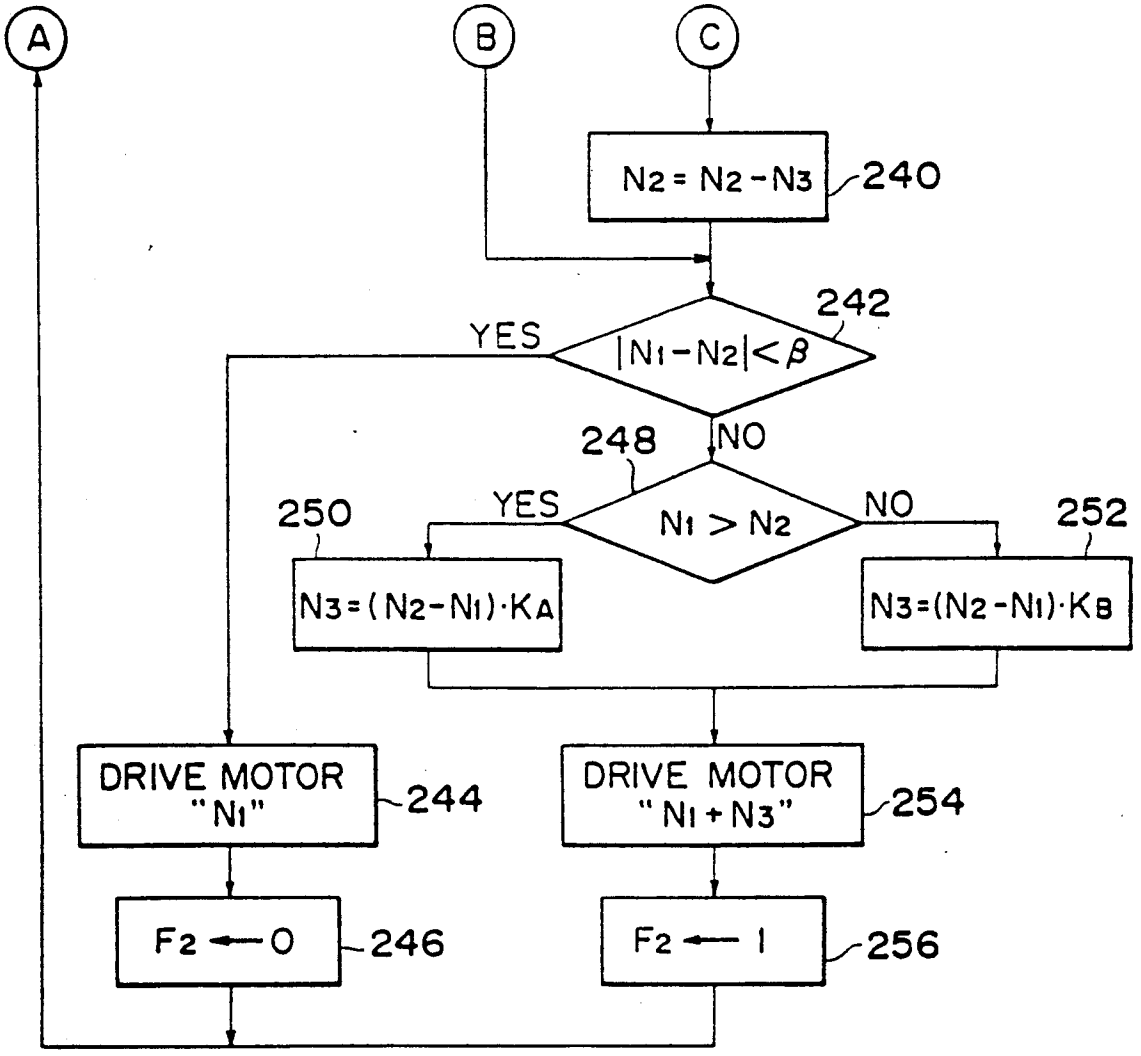

A
B
C
N2 = N2 - N3
240
242
YES
|N1 - N2| < β
NO
248
250
YES
N1 > N2
NO
252
N3 = (N2 - N1) · KA
N3 = (N2 - N1) · KB
DRIVE MOTOR "N1"
244
DRIVE MOTOR "N1 + N3"
254
F2 ← 0
246
F2 ← 1
256

FIG. 4(a)

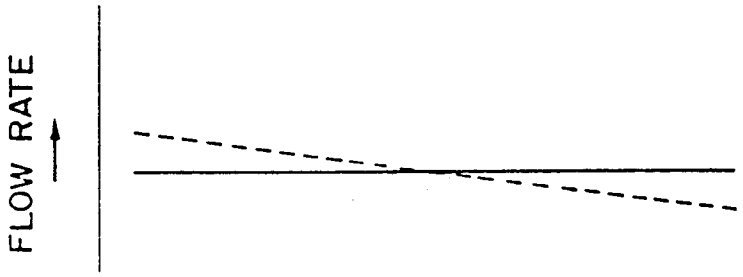


FIG. 4(b)

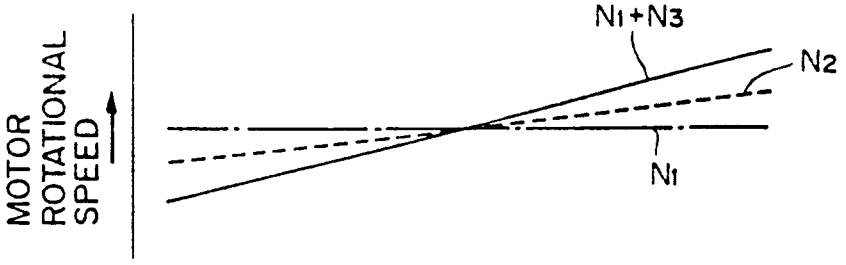


FIG. 4(c)

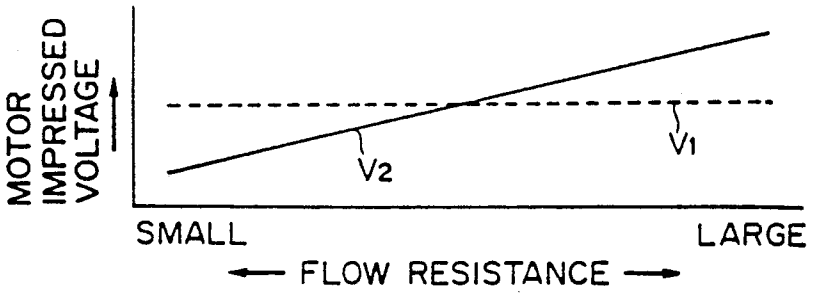


FIG. 5

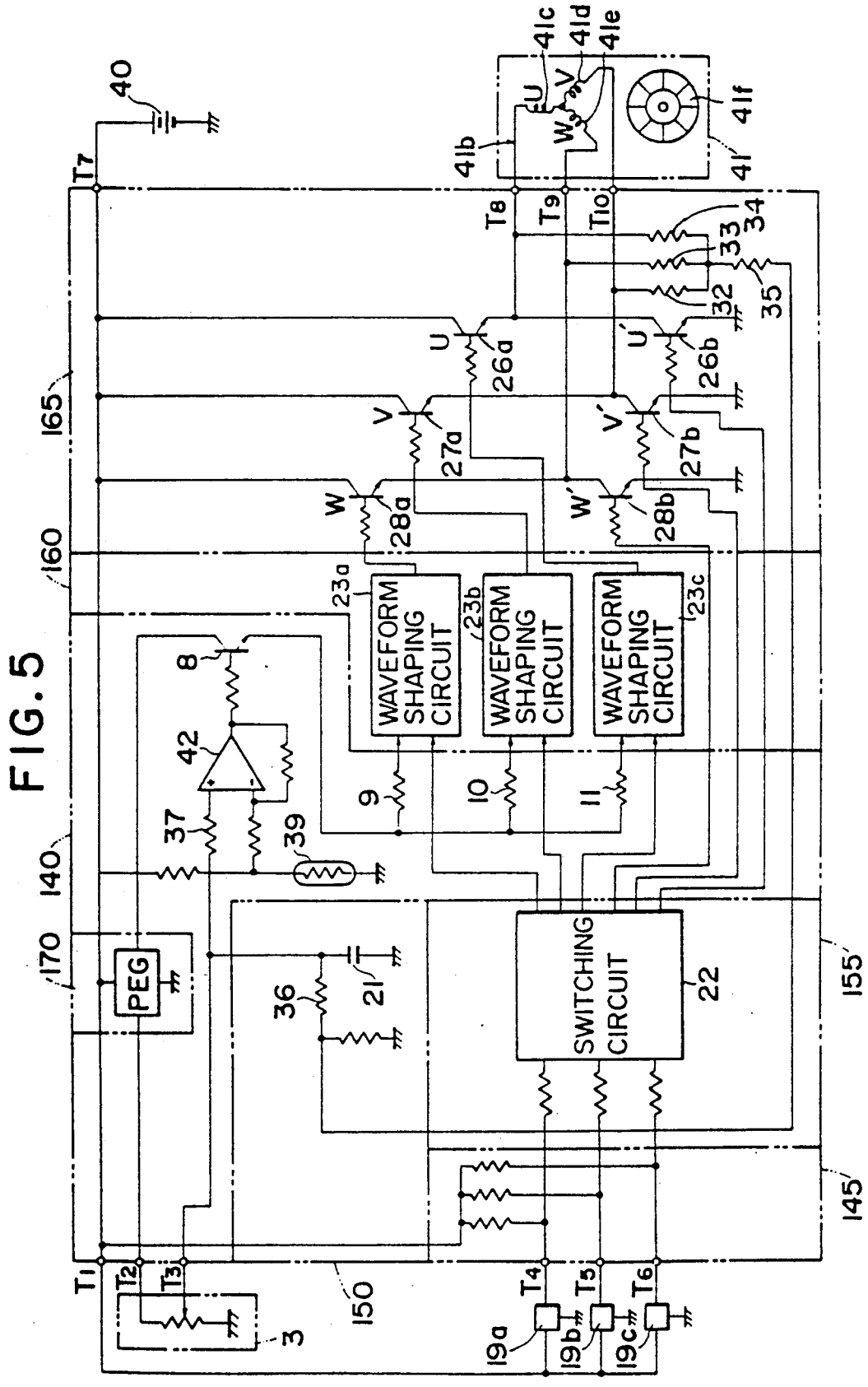

40
T7
41c
41d
41e
41b
41f
41
T8
T9
T10
33
34
32
35
U
26a
U'
26b
V
27a
V'
27b
W
28a
W'
28b
165
160
23a
23b
23c
WAVEFORM SHAPING CIRCUIT
WAVEFORM SHAPING CIRCUIT
WAVEFORM SHAPING CIRCUIT
8
42
37
39
9
10
11
140
170
PEG
36
21
SWITCHING CIRCUIT
22
155
145
T1
T2
T3
150
T4
T5
T6
3
19a
19b
19c

FIG. 6

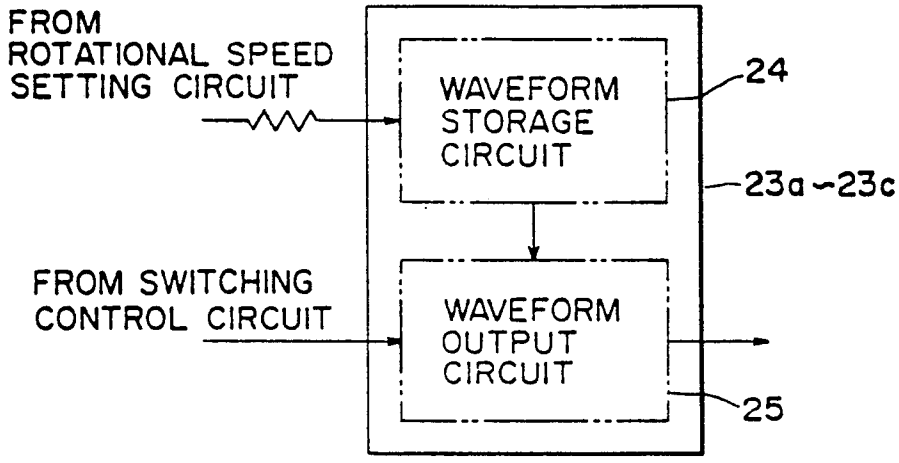


FIG. 8(a)



FIG. 8(b)

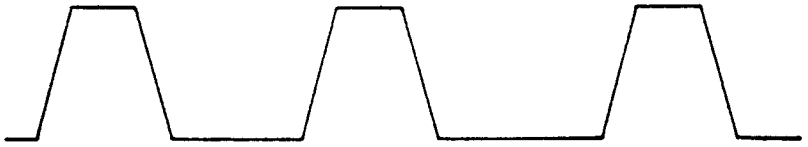
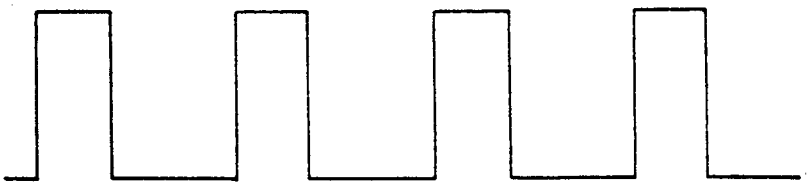


FIG. 8(c)



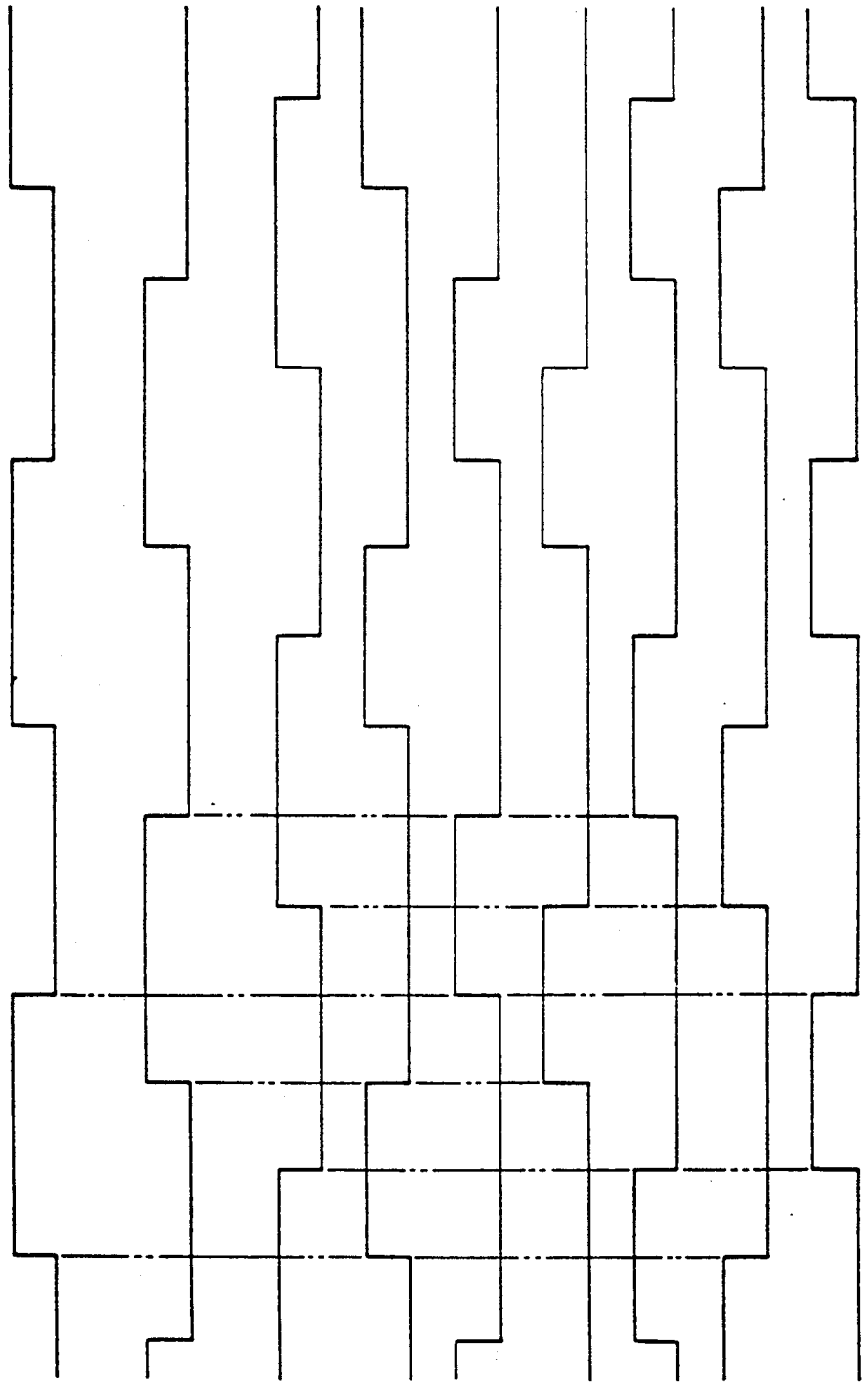


FIG. 7(a)
FIG. 7(b)
FIG. 7(c)
FIG. 7(d)
FIG. 7(e)
FIG. 7(f)
FIG. 7(g)
FIG. 7(h)
FIG. 7(i)

APPARATUS FOR CONTROLLING BLOWER MOTOR OF AUTOMOBILE AIR-CONDITIONER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to apparatus for controlling a blower motor composed of a brushless motor.

2. Description of the Prior Art

Blowers of automobile air-conditioners generally comprise a sirocco fan driven by a motor. When the operation of the automobile air-conditioners is changed from the vent mode in which the flow resistance within an air-flow duct is relatively small, to the defrost mode in which the flow resistance in the air-flow duct is relatively large, the performance characteristics of the conventional blowers are such that the flow rate of the sirocco fan decreases while at the same time the motor rotational speed increases. At the time of this mode change, if a control is achieved to maintain the speed of rotation of the motor at a constant level, the flow rate of the sirocco fan will be considerably reduced in the defrost mode.

In recent years, a demand for a silent vehicle passenger compartment has greatly increased with the prolonged service life of motor vehicles. This demand involves a study of sound reduction of a blower motor which constitutes a noise generating source. The conventional blower motor is equipped with brushes and hence is structurally limited as to the reduction of the noise level.

With this difficulty in view, an attempt has been made to realize a blower motor composed of a brushless motor as the size and manufacturing cost of the brushless motor are progressively reduced. To control rotation of such a brushless motor, the speed of rotation of a rotor of the brushless motor is detected by a Hall-effect element rotor and a signal proportional to the detected rotor revolution speed is converted into a voltage signal which in turn is compared with a predetermined reference voltage so as to maintain the difference between two compared signals at a constant value. This rotation control system is disclosed in Japanese Patent Laid-open Publication No. 58-36184. Japanese Patent Laid-open Publication No. 58-54884 discloses another rotation control system in which the power voltage is regulated with a change in rotational speed of the brushless motor.

SUMMARY OF THE INVENTION

With the foregoing difficulties in view, it is an object of the present invention to provide an apparatus for controlling a blower motor of an automobile air-conditioner which is capable of preventing undue changes in the flow rate of the blower motor even when the flow resistance varies.

According to a first aspect of the present invention, there is provided an apparatus for controlling a blower motor of an automobile air-conditioner, including target rotational speed setting circuitry for setting a target speed of rotation for a blower motor composed of a brushless motor; a rotation sensor for detecting a current speed of rotation of the blower motor; rotational speed correcting circuitry for correcting an output signal from the target rotational speed setting circuitry according to the difference between a setting value from the target rotational speed setting circuitry and a detected value from the rotation sensor; and driving circuitry for driving the blower motor according to an output signal from the rotational speed correcting circuitry.

In a stable condition in which the flow resistance does not change, the blower motor is driven by the drive circuitry according to the setting value from the target rotational speed setting circuitry. When the detected value from the rotation sensor varies with changes in flow resistance, the output signal from the target rotational speed setting circuitry is corrected by the rotational speed correcting a circuitry so as to cancel out or taken up changes in flow rate.

According to a second aspect of the present invention, there is provided an apparatus for controlling a blower motor of an automobile air-conditioner, the blower motor being composed of a brushless motor, the apparatus including rotational speed setting circuitry for setting a speed of rotation for the brushless motor; drive circuitry for driving the brushless motor while controlling excitation of the brushless motor in such a manner that the speed of rotation of the brushless motor is in equal to a value set by the rotational speed setting circuitry; and switching control means operatively connected to the drive circuitry for controlling excitation timing of the brushless motor achieved by the drive circuitry.

With this construction, the blower motor composed of the brushless motor is driven by the driven circuitry according to a rotational speed set by the rotational speed setting circuitry. Since there is no feedback loop provided for maintaining a constant rotational speed, a change in flow resistance, if occurs, causes the rotational speed to vary correspondingly.

The above and other objects, features and advantages of the present invention will become manifest to those versed in the art upon making reference to the detailed description and the accompanying sheets of drawings in which preferred structural embodiments incorporating the principles of the present invention are shown by way of illustrative example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an operational block diagram of an apparatus for controlling a blower motor of an automobile air-conditioner according to a first embodiment of the present invention;

FIG. **2** is a pictorial block diagram showing the general construction of the blower motor controlling apparatus;

FIGS. **3**(*a*) and **3**(*b*) are flowcharts showing a control routine achieved by a microcomputer incorporated in the apparatus for controlling the operation of the blower motor;

FIG. **4**(*a*) is a graphic representation of a performance curve showing the relationship between the flow resistance and the flow rate of the blower motor;

FIG. **4**(*b*) is a graphic representation of a performance curve showing the relationship between the flow resistance and the motor rotational speed;

FIG. **4**(*c*) is a graphic representation of a performance curve showing the relationship between the flow resistance and the motor impressed voltage;

FIG. **5** is a circuit diagram of an apparatus for controlling a blower motor of an automobile air-conditioner according to a second embodiment of the invention;

FIG. 6 is a block diagram of a waveform shaping circuit of the apparatus shown in FIG. 5;

FIGS. 7(*a*)–7(*i*) are timing charts showing detected signals of Hall-effect elements and operation timings of respective transistors in a driver circuit of the apparatus shown in FIG. 5; and

FIGS. 8(*a*)–8(*c*) are views showing waveforms of output signals issued from the waveform shaping circuit shown in FIG. 6.

DETAILED DESCRIPTION

The general construction of an apparatus for controlling a blower motor of an automobile air-conditioner embodying the present invention will be described below with reference to FIG. **1**.

The apparatus generally includes target rotational speed setting unit **100** for setting a target speed of rotation for a brushless motor **41**, a rotation sensor **110** for detecting current speed of rotation of the brushless motor **41**, a rotational speed correcting unit **120** for correcting an output signal from the target rotational speed setting unit **100** according to the difference between a setting value from the target rotational speed setting unit **100** and a detected value from the rotation sensor **110**, and driving unit **130** for driving the brushless motor **41** according to an output signal from the rotational speed correcting unit **120**.

Structural details of the apparatus will be described below with reference to FIG. **2**.

The automobile air-conditioner includes an air-flow duct **1** and a blower **2** disposed in the air-flow duct **1** adjacent to the upstream end thereof. The blower **2** has a sirocco fan **2***a* mounted on a blower motor composed of a brushless motor **41**.

The brushless motor **41** is of the construction known per se including a rotor formed of a permanent magnet, armature coils for producing a rotating magnetic field, and a Hall-effect element. A typical example of such brushless motor **41** is disclosed in Japanese Utility Model Application No. 63-97171. Structural components of the brushless motor do not constitute an essential part of the present invention and hence a further description is not necessary.

The apparatus includes a rotational speed setter **3** for setting the speed of rotation of the brushless motor **41**. The rotational speed setter **3** is composed of a variable resistor having a slidably movable terminal **3***a* from which an output voltage is delivered to an analog-to-digital (A/D) converter **4**. The A/D converter **4** converts the thus received voltage signal into a digital signal which in turn is inputted into a microcomputer **5**.

The microcomputer **5** is of the construction known per se including a central processing unit (CPU), a read only memory (ROM), a random access memory (RAM), an input/output port, etc.

The microcomputer **5** receives an output signal from the Hall-effect element (not shown) disposed inside the brushless motor **41**.

Based on input signals received from the A/D converter **4** and the non-illustrated Hall-effect element, the micro-computer **5** computes a control signal required for the control of rotation of the brushless motor **41** according to a program stored in the ROM and outputs the thus computed control signal. The control signal thus outputted is then delivered to a digital-to-analog (D/A) converter **6** connected to the output side of the microcomputer **5**. The D/A converter **6** supplies the control signal as an analog signal to a motor driving circuit **7** which in turn is operative to control the operation of the brushless motor **41**.

The microcomputer **5** shown in the illustrated embodiment is constructed so as to control the operation of non-illustrated components of the automobile air-conditioner, but, it may be provided exclusively for the control of the blower motor.

The control of the operation of the brushless motor **41** achieved by the microcomputer **5** will be described with reference to a control flowchart shown in FIGS. **3**(*a*) and **3**(*b*).

The microcomputer **5** starts its control routine in a step **200**. Then the control proceeds to a step **202** to initialize variables. Typical examples of such variables to be initialized include a flag F_1 and a flag F_2. After the flags F_1, F_2 are set to zero, the control goes on to a step **204**.

The flag F_1 is used to judge whether the current execution of the control program is a first time which immediately follows the start of the apparatus, or a second or succeeding time. If the judgment indicates the second or succeeding time, then the flag F_1 is set to "1". The flag F_2 is used to make a judgment as to whether or not the correction of rotation of the brushless motor **41** is achieved. If yes, the flag F_2 is set to "1".

At step **204**, information is input about the current discharge mode position of a non-illustrated mode door of the air-conditioner which is selectively set in a vent mode position, a defrost mode position and a foot mode position. The mode position information are inputted in terms of a variant MP of predetermined values.

In the case where the microcomputer **5** is used for the control of the entire operation of the air-conditioner, the information about the mode position are inputted from a main program stored in the microcomputer **5**.

The control proceeds to a step **206** in which the rotational speed setter **3** inputs a setting rotational speed $N\phi$. Then, the control advances to a step **208**.

At step **208**, the setting rotational speed $N\phi$ is corrected by multiplying the same by an arithmetic constant K_M. The constant K_M is determined depending on the discharge mode and is set, for example, to have a maximum value in the defrost mode, a minimum value in the foot mode, and an intermediate value in the vent mode.

The step **208** is followed by a step **210** in which a judgment is made to determine whether or not the flag F_1 is zero. If zero (YES), this means that the current operation of the control program takes place at a first time immediately after the start of the apparatus. Then, the control advances to a step **214**. Alternatively, if F_1 is not zero (NO), the control goes on to a step **212**.

At step **214**, a judgment is made as to whether the flag F_2 is zero. If zero (YES), this means that the correction of rotation in a step **220** or a step **254** described later is not effected. Then the control goes on to a step **220** in which a control signal corresponding to the rotational speed $N\phi$ which is calculated in the above-mentioned step **208** is applied to the motor driving circuit **7**, thereby driving the brushless motor **41**. The step **220** is followed by a step **222** in which the flag F_1 is set to "1" and the control goes on to a step **224**.

In the, case where the judgment in the step **214** indicates that F_2 is other than zero (NO), this means that the rotational speed is corrected by a step **254** described later. Then the control advances to a step **216** in which $N\phi$ is renewed by multiplying the $N\phi$ which is obtained in the above-mentioned step **208**, by $(N_1+N_3)/N_1$

where N_1 is a target rotational speed which is set in the step **212**. The target rotational speed is a rotational speed which is set at the input side of the motor driving circuit **7** under such conditions that the flow resistance is kept constant and the brushless motor **41** is rotating stably. In practice, a voltage signal corresponding to such a target rotational speed is supplied from the D/A converter **6** to the motor driving circuit **7**. When the flow rate changes with a change in flow resistance, the rotational speed of the brushless motor **41** is corrected (in the step described later) to restore the initial flow rate. The thus corrected rotational speed is designated by N_3 and referred to as a corrected rotational speed.

FIG. **4** indicates the relationship between the flow rate, motor rotational speed and motor impressed voltage with respect to changes of the flow resistance in the air-flow duct **1** occurring when the discharge mode is changed. In FIG. **4**(*b*), a dash-and-dot line corresponds to the above-mentioned N_1, a solid line corresponds to N_1+N_3 stated above, and a broken line corresponds to a rotational speed N_2 which is detected when the flow rate is changed due to changes in flow resistance.

As described above, the setting rotational speed $N\phi$ is renewed or changed in the step **216**. This is because the setting rotational speed must be changed at the same ratio as the amount of correction of the actual rotational speed effected by N_3 in the step **254** in order to maintain the effect of correction by N_3 even at a time of subsequent change of the setting rotational speed by the rotational speed setter **3**.

After the arithmetic operation in the step **216** is completed, the control advances to the step **218** so as to set F_2 to zero. Then the control goes on to the step **220** in which a voltage corresponding to $N\phi$ is applied to the input terminal of the motor driving circuit **7** so as to drive the brushless motor **41** at a value $N\phi$ calculated in the step **216**. This step **220** is followed by the step **222** described above.

At step **212** a judgment is made to determine whether the target rotational speed $N_1$is in equal to the setting rotational speed $N\phi$. If $N_1=N\phi$ (YES), then the control proceeds to the step **224**. Alternately, if $N_1\neq N\phi$ (NO), the control returns to the step **214**.

At step **224**, the current actual motor rotational speed N_2 is inputted based on the detected signal from the Hall-effect element. Then the control advances to step **226** in which the motor rotational speed inputted in the step **224** is set to a variable $N_{2(a)}$. The control further advances to a step **228** in which a timer is started to provide a predetermined period of time before the start of the next following operation. When the predetermined time period elapses, the control goes on to a step **230**.

At step **230**, the actual motor rotational speed N_2 is detected again and, thereafter, the control advances to a step **232** in which the detected value is set to a variable $N_{2(b)}$. The control advances to a step **234**.

At step **234**, a judgment is made to determine whether an absolute value of the difference between a value of $N_{2(a)}$ and a value of $N_{2(b)}$ is smaller than a predetermined value α. If the absolute value is smaller than α (YES), this means that the rotation of the motor is in the stable state. Then the control returns to the step **224** stated above. If the absolute value is equal to or greater than α (NO), this means that the rotation of the motor is in the unstable state. In this case, the control advances to a step **236**.

At step **236**, the setting rotational speed $N\phi$ is set to N_1 and, thereafter, the control goes on to a step **238** in which a judgment is made to determine whether or not F_2 is zero. If the judgment indicates $F_2=O$ (YES), the control jumps over a step **240** to a step **242**. Conversely, if $F_2\neq 0$ (NO), the control advances to the step **240** in which the difference between N_2 and N_3 is set to N_2. Thereafter, the control advances to the step **242**.

At step **242**, a judgment is made to determine whether or not an absolute value of the difference between N_1 and N_2 is smaller than a predetermined value or not. If the absolute value is smaller than (YES), this means that a change in motor rotational speed is relatively small and correction of rotational speed is unnecessary. Then the control goes on to a step **244** in which the target rotational speed N_1 is maintained to control operation of the brushless motor at this speed. The step **244** is followed by a step **246** so to set F_2 to zero and, thereafter, the control returns to the step **204** from which the foregoing operations are repeated.

If the judgment in the step **242** indicates that the absolute value is equal to or smaller than β (NO), then the control advances to a step **248** in which a judgment is made to determine whether or not N_1 is greater than N_2 or not. If $N_1>N_2$ (YES), the control goes on to a step **250** in which N_3 is substituted by a value obtained by multiplying the difference between N_1 and N_2 by a predetermined arithmetic constant K_A. If $N_1>N_2$ (NO), then the control goes on to a step **252** in which N_3 is substituted by a value obtained by multiplying the difference between N_1 and N_2 by a predetermined arithmetic constant K_B. At step **252** or the step **250** is followed by the step **254** in which N_3, calculated in the step **250** or the step **252**, is added to and a resulting value is outputted to the motor driving circuit **7**, thereby driving the brushless motor. This step is practically achieved by changing the voltage impressed to the brushless motor **41** from a target voltage V_1 (indicated by the broken line in FIG. **4**(*c*)) corresponding to the uncorrected target rotational speed N_1, to a voltage V_2 (indicated by the solid line in the same Figure) corresponding to the sum of N_1 and N_2.

The step **254** is followed by a step **256** in which F_2 is set to "1" and then the control returns to the step **204**.

The operation of the apparatus of the foregoing construction is as follows. A non-illustrated start switch is actuated to start the operation of the apparatus. In this instance, if the discharge mode is the vent mode, the rotational speed setter **3** sets a relatively low rotational speed. The input terminal of the motor driving circuit **7** is supplied with a voltage which is corresponding to the setting rotational speed $N\phi$. Thus, the brushless motor **41** is excited. Immediately after the start of the brushless motor **41**, the motor rotational speed increases gradually toward $N\phi$ and hence setting of $N\phi$ to N_1 is retarded until after rotation of the brushless motor becomes stable to a certain extent. Thereafter, when the difference between N_1 and N_2 falls within an allowable range, the microcomputer **5** output N_1 to the motor driving circuit **7**, thereby driving the brushless motor (see steps **224** through **238** and steps **242** through **246** described above).

While the brushless motor **41** is operating stably at the target rotational speed N_1, the discharge mode is changed from the vent mode to the defrost mode. This mode change causes a reduction of the flow rate and an increase in flow resistance which will increase the rotational speed of the brushless motor **41**. In this instance,

a correction of the rotational speed is performed to further increase the rotational speed of the brushless motor **41** so as to accommodate the reduction of the flow rate (see step **254** described above). After Nϕ is corrected to such an extent equivalent to N_3 (see step **254** described above), the brushless motor **41** is driven by the thus corrected Nϕ so that the rotational speed of the brushless motor **41** is stabilized. When the difference between the actual motor rotational speed N_2 and Nϕ falls within the allowable range, then a value of Nϕ set to N_1 is supplied, as a new target rotational speed, from the microcomputer **5** to the motor driving circuit **7** in the same manner as done at the start of the apparatus.

An apparatus for controlling a blower motor of an automobile air-conditioner according to a second embodiment of the present invention will be described below with reference to FIG. **5**.

The blower motor control apparatus includes a rotational speed setting circuit **140**, a rotational speed detection circuit **145**, an arithmetical mean circuit **150**, a switching control circuit **155**, a drive input control circuit **160**, a driver circuit **165** and a voltage-regulating transformer circuit **170**. A rotational speed setter **3** composed of a variable resistor is connected between external terminals T_2 and T_3. Likewise, Hall-effect elements **19***a*, **19***b*, **19***c* constituting a part of the rotation detection circuit **145** are connected between an external terminal T_1 and external terminals T_4—T_1 A direct-current (dc) power supply **40** is connected to an external terminal T_7 and a brushless motor **41** is connected to external terminals T_8—T_{10}. The rotational speed setting circuit **140** is constructed to set a rotational speed for the brushless motor **41** and includes a differential amplifier circuit composed mainly by an operational amplifier **42**, and a distributing circuit composed mainly by a transistor **8**.

To a non-inverted input terminal of the operational amplifier **42**, a voltage which corresponds to the setting rotational speed set by the externally connected rotational speed setter **3** and an output voltage from the arithmetic mean circuit **150** described later are applied. The inverted input terminal of the operational amplifier receives a reference voltage. The difference between the input voltage applied to the non-inverted input terminal and the reference voltage applied to the inverted input terminal is amplified and the thus amplified voltage is applied to the base terminal of the transistor **8**. An output voltage delivered from the emitter terminal of the transistor **8** is inputted through resistors **9**–**11** to the drive input control circuit **160**.

A temperature sensor **39** composed of a thermistor having a negative temperature coefficient of resistance, for example, is connected to the inverted input terminal of the operational amplifier **42** of the rotational speed setting circuit **140**. The temperature sensor **39** functions to adjust the output level of the arithmetic mean circuit **150** according to the vehicle passenger compartment temperature and the motor temperature. In other words, the temperature sensor **39** is disposed in the vehicle passenger compartment or in the brushless motor **41**. Since resistance of the temperature sensor **39** decreases with an increase in temperature detected by the temperature sensor **39**, the input level of the arithmetic mean circuit **150** relative to the operational amplifier **42** is lowered. Conversely, the resistance of the temperature sensor **39** increases with a reduction in temperature detected by the temperature sensor **39** so that the input level to the operational amplifier **42** is increased by the temperature sensor **39**. Thus, the temperature sensor **39** serves to compensate for fluctuations of motor output power caused by changes in temperature. This temperature compensation is employed in view of the tendency that the motor output power is large at low temperatures and is low at high temperatures. However, since the brushless motor **41** is kept in the air-cooled condition by the sirocco fan, a appreciable temperature rise never occurs and hence the fluctuation of the output power is negligible.

The rotation detection circuit **145** is constructed to detect the rotation of a rotor **41***f* of the brushless motor **41** and is composed mainly of the three Hall-effect elements **19***a*–**19***c* disposed adjacent to the rotor **41***f* via the external terminals T_4–T_6.

The Hall-effect elements **19***a*–**19***c* comprise a magnetic sensor capable of producing an output signal the magnitude of which is variable proportional to the direction and strength of an external magnetic field acting on the Hall-effect elements **19***a*–**19***c*.

The three Hall-effect elements **19***a*–**19***c* are provided in view of the stator windings **41***b* which are composed of three-phase windings so that they are disposed adjacent to the rotor **41***f* at equal angular intervals of 120 degrees. The first to third Hall-effect elements **19***a*–**19***c* output signals H_U, H_V, H_W respectively at timings shown in FIGS. 7(*a*)–7(*c*) as the rotor **41***f* revolves.

The arithmetic mean circuit **120** is constructed to feed back to the operational amplifier **42** an arithmetic mean value of the respective phase voltages of the stator windings as a feedback signal.

More particularly, the arithmetic mean circuit **120** is constructed to pickup the phase voltages of the respective phase windings **41***c*–**41***e* via resistors **32**–**34**. The phase voltages are added or combined at a resistor **35** which in turn an added voltage is applied via a resistor **36** to a capacitor **21**. Thus, the voltage appearing across the capacitor **21** is obtained by the following expression

$$V=K\cdot(V_U+V_V+V_W)/3$$

where V_U, V_V and V_W are voltages applied to the respective phase windings **41***c*–**41***e*, and K is a constant.

On end of the capacitor **21** opposite to the ground side is connected via a resistor **37** to the non-inverted input terminal of the operational amplifier **42**.

The switching control circuit **155** is construct to determine the driving timing of transistors **26***a*, **26***b*, **27***a*, **27***b*, **28***a*, **28***b* that form the driver circuit **165** described later. The switching control circuit **155** is composed mainly by a switching circuit **22** having a logic circuit which is constructed so as to output switching signals shown in FIGS. 7(*d*)–7(*i*) based on the output signal from the rotation detecting circuit **145**. In FIGS. 7(*d*)–7(*i*), reference characters U, V, W, U', V'and W' correspond to the transistors **26***a*, **26***b*, **27***a*, **27***b*, **28***a* and **28***b* shown in FIG. **5** and respective signal illustrate on-off timing of the corresponding transistors **26***a*, **26***b*, **27***a*, **27***b*, **28***a* and **28***b*.

The drive input control circuit **160** is constructed to receive the output signal from the rotational speed setting circuit **140** and the output signals from the switching control circuit **155** and output a drive signal to the driver circuit **165** under the control of the timing of the output signals received from the switching control circuit **155**, the driving signal corresponding to the setting rotational speed.

The drive input control circuit **160** is composed mainly of three identical waveform shaping circuits **23***a*–**23***c*.

As shown in FIG. **6**, each of the waveform shaping circuits **23***a*–**23***c* is composed of a waveform storage circuit **24** and a waveform output circuit **25**.

The waveform storage circuit **24** serves to vary the output waveform of the drive input control circuit **160** according to the motor rotational speed. It is constructed to store three different waveforms such as shown in FIG. **8**. When the setting rotational speed for the brushless motor **41** is a low speed (i.e., when the output voltage from the rotational speed setting circuit **140** is low), the waveform storage circuit **24** outputs a signal having a sine waveform shown in FIG. **8**(*a*). In the case where the setting rotational speed for the brushless motor **41** is an intermediate speed (i.e., when the output voltage from the rotational speed setting circuit **140** is intermediate), the waveform storage circuit **24** outputs a signal having a trapezoidal waveform shown in FIG. **8**(*b*). And, when the setting rotational speed for the brushless motor **41** is a high speed (i.e., when the output voltage from the rotational speed setting circuit **140** is high), a signal having a square waveform shown in FIG. **8**(*c*) is outputted from the waveform storage circuit **24**.

On the other hand, the waveform output circuit **25** is constructed to receive the output signals from the waveform storage circuit **24**, and then amplify the same at a predetermined amplification degree substantially direct proportional to the magnitude of output voltage of the rotational speed setting circuit **140** and output the amplified output signal to the driver circuit **165** in accordance with the timing of the output signals from the switching control circuit **155**.

The driver circuit **165** is constructed to control excitation of the respective phase windings **41***c*–**41***e* of the stator windings **41***b* of the brushless motor **41**. It is composed mainly of the transistors **26***a*, **26***b*, **27***a*, **27***b*, **28***a*, **28***b*.

Each of the transistors **26***a*, **26***b*, **27***a*, **27***b*, **28***a*, **28***b* is turned on and off depending on the output timing of a corresponding one of the output signals issued from the switching control circuit **155** and the drive input control circuit **160**. The transistors **26***a*, **26***b*, **27***a*, **27***b*, **28***a*, **28***b* also serve to supply an exciting current through the terminals T_8–T_{10} to the stator windings **41***b* according to the output voltage received from the drive input control circuit **160**. The on-off operation of the respective transistors **26***a*, **26***b*, **27***a*, **27***b*, **28***a*, **28***b* is controlled in the manner as shown in FIGS. **7**(*d*)–**7**(*i*). With this controlled excitation of the respective phase windings, a rotating magnetic field is produced in the brushless motor **6** rotating in the direction from the U-phase to the V-phase and then to the W-phase.

The voltage-regulating transformer circuit **170** is connected to the externally connected dc power supply **40** to regulate the output voltage so as to output a stable dc voltage. The voltage-regulating transformer circuit **170** comprises an transformer element composed of an integrated circuit IC package know per se and has a function to reduce a dc 12V to a dc 5V.

The brushless motor **41** connected via the external terminal T_8–T_{10} to the apparatus is of the type known per se including the stator windings **41***b* having the U-phase, V-phase and W-phase windings **41***e*—**41***e*, and the rotor **41***f* composed of a permanent magnet, and hence a further description is not necessary.

The blower motor control apparatus of the foregoing construction will operate as follows. The rotational speed setter **1** is set to a relatively low speed of rotation before the operation of the apparatus begins. When a non-illustrated power switch is turned on to energize the dc power supply **40**, the voltage applied to the non-inverted input terminal is amplified at a predetermined amplification degree and the thus amplified voltage is output from the output terminal of the operational amplifier **42**. In proportion to the output voltage, an exciting current flows through the stator windings **41***b* whereupon the rotor **41***f* is rotated. In this instance, the exciting current has a sign waveform such as shown in FIG. **8**(*a*) due to the operation of the drive input control circuit **160**. The starting operation of the brushless motor **41** begins smoothly without an unpleasant beat noise which may be generated from the stator windings **41***b* due to a rush current applied thereto at the start of the brush motor when a square waveform signal is used. As the rotational speed of the rotor **41***f* approaches the setting rotational speed, the output voltage from the arithmetic mean circuit **150** gradually increases. As a result, the non-inverted input terminal of the operational amplifier **42** is supplied with a combination of the voltage corresponding to the setting rotational speed set by the rotational speed setter **3** and the output voltage from the arithmetic mean circuit **150**. In this instance, if the voltage applied to the stator windings **41***b* is stable, that is the power voltage is stable, the output voltage from the arithmetic mean circuit **150** has a predetermined value. Thus, an amplified signal which corresponds to the difference between the sum of this predetermined value and the output voltage of the rotational speed setter **3**, and the reference voltage applied to the inverted input terminal appears at the output terminal of the operational amplifier **42** and the circuitry retains this stable condition.

When the impressed voltage on the stator windings **41***b* drops for some reason, the output voltage from the capacitor **21** is lowered, thereby lowering the impressed voltage on the non-inverted input terminal of the operational amplifier **42**. Consequently, the input signal of the driver circuit **165** becomes small whereupon the exciting current flowing through the stator windings **41***b* is reduced, thereby reducing the voltage drop in the respective phase windings **41***c*–**41***e*. This cancels out or compensates the previous voltage drop so that the impressed voltage is kept substantially constant at all the times. In other words, the voltage applied to the stator windings **41***b* is kept at a constant level and hence a control of the brushless motor **41** under the condition of a constant flux control can be performed.

Obviously, various modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the present invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An apparatus for controlling a blower motor in an automobile air-conditioner, the blower motor being composed of a brushless motor, said apparatus comprising:

(a) rotational speed setting means for setting a speed of rotation for the brushless motor;

(b) drive means for driving the brushless motor while controlling excitation of the brushless motor in such a manner that the speed of rotation of the

brushless motor is in equal to a value set by said rotational speed setting means; and

(c) switching control means operatively connected to said drive means for controlling excitation timing of the brushless motor achieved by said drive means;

wherein said driving means includes a waveform storage means for changing the waveform of a voltage to be impressed to the brushless motor according to an output signal from said rotational speed setting means, said waveform storage means outputting an impressed voltage having a sine waveform when the rotational speed set by said rotational speed setting means is a low rotational speed, outputting an impressed voltage having a substantially trapezoidal waveform when the rotational speed set by said rotational speed setting means is an intermediate rotational speed, and outputting an impressed voltage having a square waveform when the rotational speed set by said rotational speed setting means is a high rotational speed.

* * * * *